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MIMES AND GEOSHACK

UNITED STATES NAVAL ACADEMY

MULTIPLE INTEGRATED MICROSPACECRAFT EXPLORATION SYSTEM

It is the goal of mankind to eventually visit Mars. Before such a visit occurs, it would be valuable to gain scientific information about the planet. The Multiple Integrated Microspacecraft Exploration System (MIMES) is designed for that very purpose. The MIMES mission will send to Mars a spacecraft carrying five probes, each of which will descend to the martian surface to engage in scientific experiments. There will be two types of probes: a penetrator that will embed itself in the martian surface, and a soft lander. The probes will transmit scientific data to the carrier spacecraft, which in turn, will relay the information to Earth.

Launch Vehicle

MIMES includes a 115-kg carrier spacecraft, or bus, and five 15-kg probes. Each probe is a microspacecraft, which can be defined as a space vehicle with a mass under 20 kg. The entire package will be carried by a Taurus launch vehicle (see Fig. 1), which is being developed jointly by the Hercules Aerospace Company, the Defense Advanced Research Projects Agency (DARPA), and Orbital Sciences Corporation. Its upper three stages are currently used on the Pegasus, an air-launched vehicle that uses a wing to provide lift. The first stage of the Taurus is the booster used on the MX Peacekeeper missile of the U.S. Air Force.

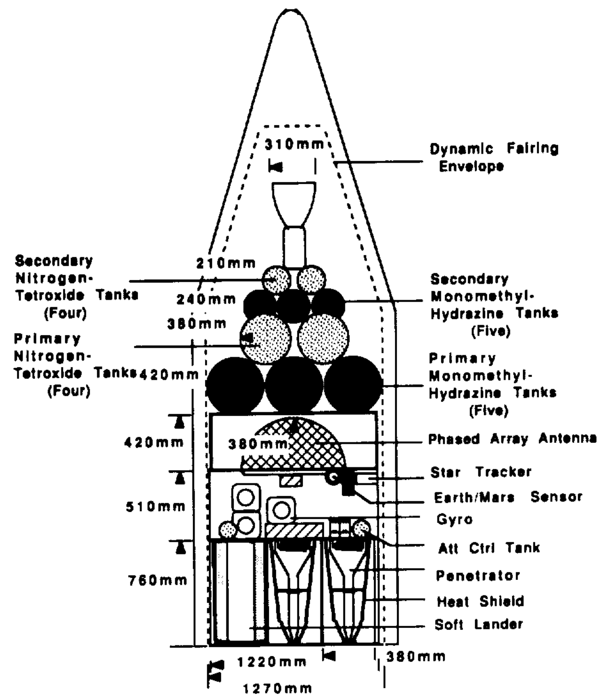

Fig. 1. Bus and Probes in Taurus Fairing

Propulsion

The MIMES bus will travel to Mars by means of a Hohmann transfer orbit. It will use a liquid bipropellant for the escape and capture burns. The fuel consists of monomethyl-hydrazine and nitrogen-tetroxide. The total mass of this fuel is 914 kg, and it is carried in four groups of tanks, with a primary and secondary group for each constituent (see Fig. 2).

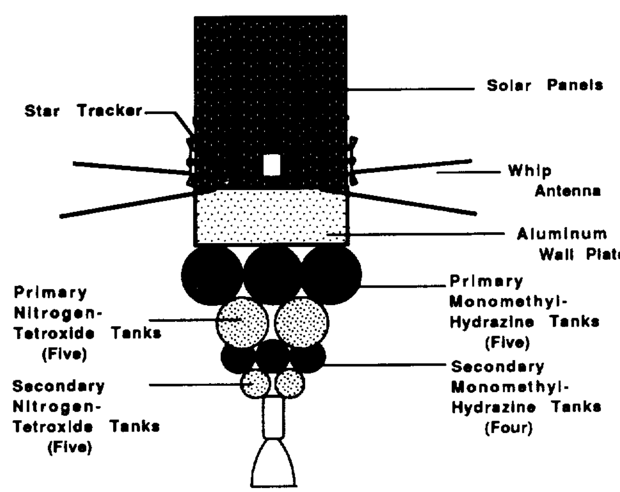

Fig. 2. Interplanetary Transfer Configuration

Orbital Mechanics

The bus will enter a circular parking orbit about the Earth at an altitude of 460 km, maintaining three-axis stabilization with monopropellant hydrazine thrusters. It will then execute the escape burn, entering a Hohmann transfer orbit about the Sun. During this stage, the bus will communicate with a ground station on the Earth by means of four omnidirectional whip antennas. It will receive its power from solar cells attached to its sides. After the bus enters the sphere of influence of Mars, but before it executes the capture burn, it

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will deploy the five probes. Each probe will be ejected out the top of the bus by the use of a spring. This will occur at a distance of approximately 40,000 km from Mars.

Atmospheric Entry

After being deployed, the probes will approach Mars and descend into the atmosphere of the planet. The probes will have heat shields made of a flexible carbon fabric coated with an ablative material, which will provide protection and aid deceleration. Each probe will separate from its heat shield and deploy a parachute. The parachutes will be designed to allow the penetrators and the soft landers to descend at speeds of 135-165 m/sec (490-590 km/hr) and 18 m/sec (65 km/hr), respectively. The penetrators, which are built of titanium, will be able to survive an impact of up to 300 *g*. The soft landers, made of aluminum, will each have an airbag to dissipate energy on impact.

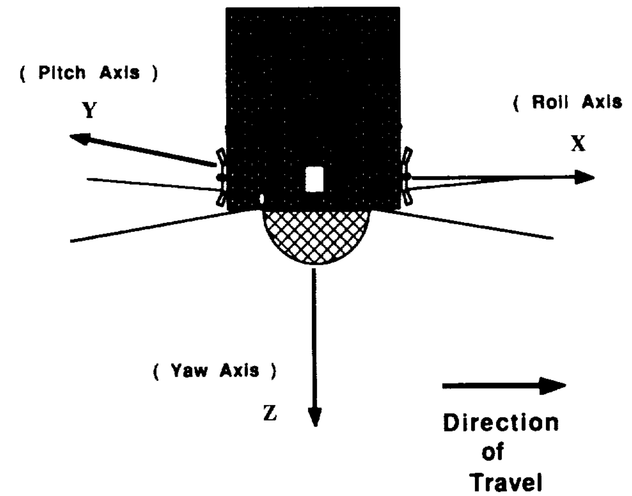

Fig. 3. Mars Orbital Configuration

Penetrator Instrumentation

After embedding themselves in the martian surface, the penetrators will begin scientific experiments. Upon entry, accelerometers will be used to determine the deceleration profiles of the penetrators. In addition, gamma-ray spectrometers will be used to analyze the martian soil. Thermal probes will also be used, determining ambient temperatures, near-surface thermal conductivity, and ambient heatflow. Finally, seismometers will be used to determine the interior structure of Mars. Ultimately, an entire network of seismic stations may be established with additional MIMES missions.

Soft Lander Instrumentation

The soft landers will conduct a variety of experiments. Each will have an atmospheric descent package that will measure temperature, pressure, density, and high-altitude wind speeds. On the ground the soft landers will become meteorological stations that measure temperature, wind speed and direction, pressure, humidity, and atmospheric dust loads. The soft landers will be able to conduct more experiments than the penetrators because they have a larger volume, yet a lower structural mass.

Orbiter Operations

After deploying the probes, the bus will execute a capture burn to enter a polar circular parking orbit at a 4500-km altitude. This altitude is high enough to avoid aerodynamic drag and significant gravity-gradient disturbance torques. It is also low enough to accommodate data received from forty probes simultaneously. Initially, the bus will not be able to receive transmissions from the probes because its phased-array antenna will be blocked by the fuel tanks. After the capture burn, the tanks will be jettisoned by means of explosive bolts, uncovering the antenna (see Fig. 3). The bus will then maintain three-axis stabilization by means of monopropellant hydrazine thrusters, contained in four small tanks within the bus. These thrusters will also be used to orient the phased-array antenna toward Earth, allowing stored data to be transmitted. Data will not be transmitted while the bus is in the shadow of Mars, as the bus will only be able to draw power from nickel-cadmium back-up batteries.

Summary

MIMES involves the use of microspacecraft for a mission that in the past has required vehicles with thousand-kilogram masses. While the MIMES penetrators and soft landers will not carry as many instruments as would such larger spacecraft, MIMES does provide the opportunity for multiple missions. Follow-on launches, with buses that do not require capture burns, would provide enough instruments on Mars' surface to collect as much data as the larger spacecraft. In addition, the MIMES probes would be carried aloft on several launches, reducing the risk of losing an entire system on a failed launch. These factors make MIMES an important consideration in the exploration of Mars.

GEOSHACK

GeoShack, the Geosynchronous Operations Support Center, is a manned spacecraft intended for use in geostationary orbit (see Fig. 4). Due to the high cost of satellites in geosynchronous equatorial orbit (GEO), their numerous and varied missions, and the heavy use of geostationary orbit, it would be beneficial to have a manned spacecraft with the specific purpose of servicing and maintaining satellites in that orbit. The spacecraft would be permanently stationed at GEO. In effect, GeoShack would be a small space station outpost. It would possess all standard crew support and servicing equipment needed for short duration missions. Astronauts would be transferred from the space station to GeoShack and return to the space station using a Space Transfer Vehicle (STV).

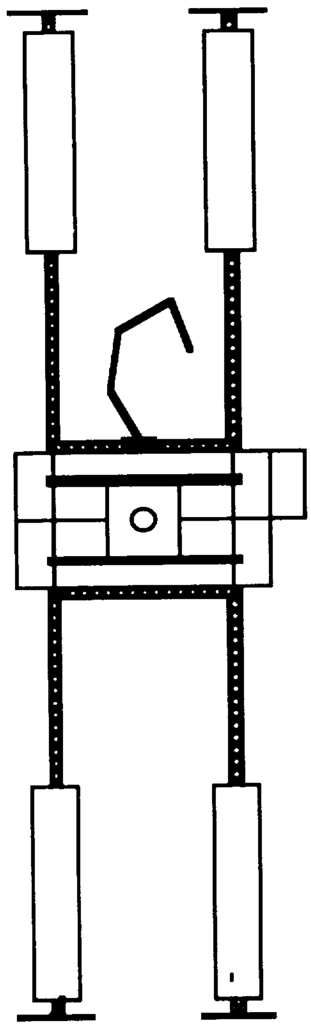

Fig. 4. GEOSHACK Orbital Configuration

Introduction

The mission of GeoShack is to service geostationary satellites and thus extend the lifetime of hardware in an increasingly crowded orbit. GeoShack was designed on the premise that it would be a long-life spacecraft that would begin functioning in the late 1990s. Imperative to this design is the presumption that the space station is manned and functional; a majority of GeoShack will be assembled at the space station.

In the design of this spacecraft, topics were divided into the following subsystems: structure, interior design, launch and assembly, propulsion, attitude control, power, thermal control, life support, communications, command and telemetry, rendezvous and docking, telerobotics and Remote Manipulator Arm (RMA), and Extravehicular Activity.

Major design constraints include:

1. Ability to rendezvous, capture, and berth spacecraft with an RMA.
2. Provide power and attitude control to the STV and attached satellites.
3. A lifetime of at least 25 years.
4. A maximum mission duration of twelve days.
5. A maximum of five EVA per mission.
6. A maximum of two satellites serviced per mission.
7. To remain unmanned for up to three years.
8. To support a maximum of four missions per year.
9. Provide a shirt-sleeve working environment.
10. Satellites will have docking interfaces and grapple fixtures.
11. Orbital transfers of the GeoShack/STV will be controlled by the STV.
12. The maximum difference in longitude of two satellites will be 30°.
13. GeoShack should not contribute to orbital debris.
14. Design should be modular with high growth potential.

Structure

Primary structure of GeoShack consists of exterior structural rings, walls of the two cylindrical modules, and four end caps. Secondary structure consists of the interior flooring and walls, which subdivide GeoShack. External structure is composed of all attachments, supports, booms, and trusses.

Interior Design

Interior design is composed primarily of the cylindrical habitat (see Fig. 5) and laboratory (see Fig. 6) modules, the major living areas. These spaces are designed with the consideration of astronaut comfort and hygiene, food preparation, growth potential, and accomplishment of the task of satellite servicing and repair.

Launch and Assembly

GeoShack will be lifted into orbit by three space shuttle launches and assembled at the space station. The first launch will carry the laboratory module, the second launch the habitat module, and the third launch solar panels, radiators, and other external structures. GeoShack will be transferred to geostationary orbit using a Space Transfer Vehicle.

Propulsion

Shack will utilize a redundant hydrazine thruster system for repositioning during satellite intercept, for space debris and collision avoidance, and during docking maneuvers.

Attitude Determination and Control

GeoShack will also use the hydrazine thruster system for its attitude control system. Solar pressure and gravity gradient are the primary disturbance torques.

Power

This spacecraft will require approximately 35 kW of power. Primary power is provided by gallium arsenide solar cells on panels. Secondary power is supplied by an energy storage

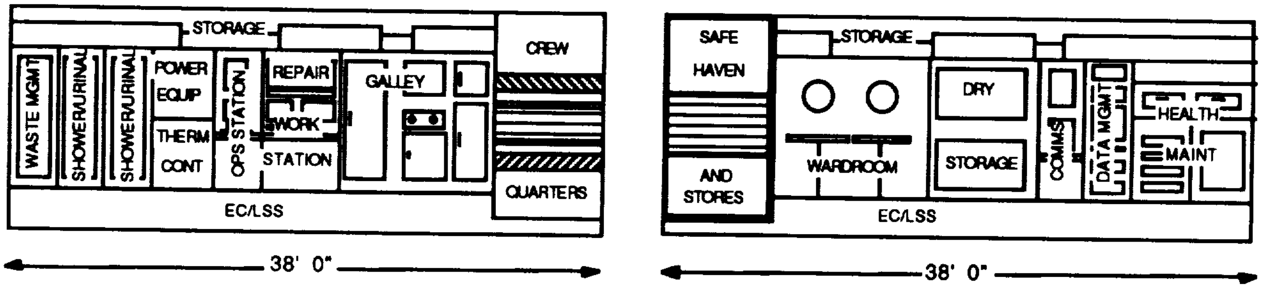

Fig. 5. Habitation Module Interior

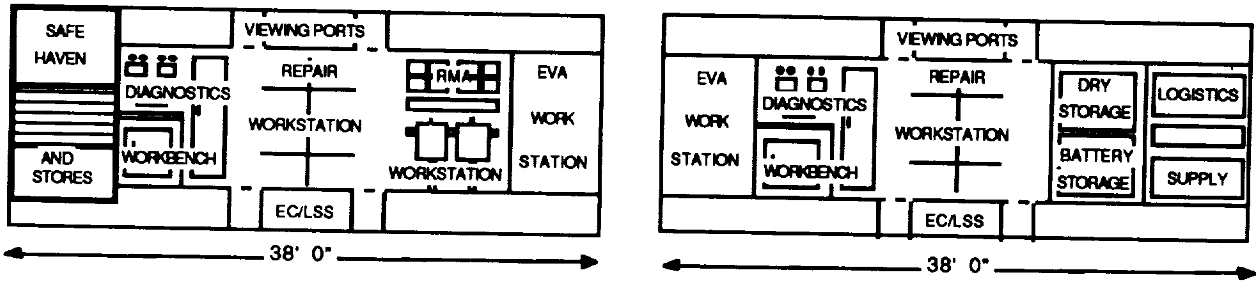

Fig. 6. Laboratory Module Interior

wheel system. An emergency backup system composed of nickel-hydrogen batteries exists to power necessary life support systems.

Thermal Control

The thermal control system consists of two basic loops. Equipment waste heat loads will be acquired via cold plates and transported to heat pipe radiators by a pumped two-phase ammonia loop. Metabolic loads will be acquired via basic air-water heat exchangers. This waste heat will be used in life support systems, and any excess heat will be transferred to the primary thermal control system for rejection.

Environmental Control and Life Support System

This system monitors and controls all systems necessary for maintaining an environment conducive to safe and healthy biological functioning of the astronauts on GeoShack. Components are temperature and humidity controls, pressurization and atmospheric revitalization systems, and water and waste management functions.

Communications, Command and Telemetry, and Data Management

The communications subsystem provides GeoShack with the voice, data, and video links necessary for successful operation. The system utilizes a one-meter parabolic dish at GeoShack and a series of three ground stations for all communications.

Satellite Rendezvous

The primary function of GeoShack is satellite repair. The first step of this process is rendezvous. Rendezvous is accomplished through use of range and range-rate sensors, which determine distance, range rate, and bearing to the target spacecraft.

Telerobotics/Remote Manipulator Arm

GeoShack possesses several automated systems to reduce the required EVA time of its astronauts. These include a four-jointed remote manipulator arm and two telerobots. These systems will be remotely controlled from within GeoShack, will make maximum use of existing technology, and will be upgradable.

EVA System

Extravehicular activity is a driving factor in GeoShack. Satellite repair will dictate that large amounts of time be spent in EVA. The system is composed of an airlock, an Extravehicular Mobility Unit, Advanced Manned Maneuvering Units, and several hard suits.

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